IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE)
ISSN : 2278-1684 Volume 1, Issue 6 (July-August 2012), PP 09-16
www.iosrjournals.org

Cold Mix Design of Semi Dense Bituminous Concrete

Om prakash yadav[1], Manjunath K.R.[2]
[1]*(Department of Civil Engineering, Dayananad sagar college of Engineering Bangalore/Visvesvaraya Technological University, Belguam / India)*

Abstract: *There is an increasing trend for using cold mix design with bitumen emulsion all over the world because of several advantages such as elimination of heating of binder and aggregate while producing mixes, this helps in protection of environment and energy conservation. In the present study, the main objective is to study the behaviour and effect of pre compaction curing on grade-2 semi dense bituminous concrete (SDBC-2) mix using bituminous emulsions treated mixtures (BETM) by Modifiefid Marshall Method of mix design. The specimen were prepared with and without filler.Comparasion was made in terms of dry and wet Marshall Stability, Marshall Flow, Volumetric properties and Indirect Tensile Strength (ITS) on Modified Marshall specimen prepared by cold mix method for SDBC-2 mix.*

In the present investigation it was found that for mixes with and without filler the Volumetric properties, dry and wet Marshall Stability, Marshall Flow and ITS.

Based on this present study it has been found that mix with cement and hydrated lime as filler each 2% both showed better results compared to mix with no filler. It has been seen that mix with 2% cement as filler showed better results compared to hydrated lime and there was no much difference in the properties for six and eight days cured specimen and hence could be concluded that six days curing period can be taken as optimum.

Keywords: *curing periods, Dry and wet stability, Marshall Flow, volumetric properties*

I. Introduction

The emissions from hot plant mixes create pollution and thus degrade the environment. The different layers of road construction require a higher temperature range for production, laying the mix, rolling; etc.Therefore bituminous road construction with Conventional paving grades Bitumen is sometimes not feasible or even not desirable in high rainfall areas as intermittent rain throughout the year affect production and laying of mixes. In snow-bond areas at high attitude, hot mixes get solidified quickly and looser their binding due to existing cold pavement surface .Use of emulsified cold mixes would eliminate the emissions and also reduce the fuel requirement at the mixing plant as energy conservation. Moreover, there is no construction specification for semi dense bituminous concrete (SDBC) with bitumen emulsion at present. In neighboring countries such as Sri Lanka and Nepal, the consumption of emulsion is about 15%, while in European countries the consumption of emulsion is up to 43%.Desipte being a versatile material with several advantages, use of bitumen emulsion in India is only about 2.7% of total consumption of bitumen. This may be probably due to the inexperience in use of this technology, non –availability of proper plants and machinery and inadequate quality of bitumen emulsion.

II. The broad scope and objectives of this study are as under:

(I)To prepare and test semi dense cold mix using emulsion by cold mix method using Marshall Equipment by conducting the laboratory study.
(ii) To evaluate the cold mix samples with emphasis on the coating, curing period, dry and wet Marshall Stability and volumetric properties, indirect tensile strength tests

III. Scope of the present study

In the present study, the binders used are tested in accordance with the standard testing procedures, i.e. emulsion is tested micron sieve, residue by evaporation, coating and demulsibility and SS-2 bitumen is tested for penetration, ductility, specific gravity and softening point. The aggregates are tested for impact value, Los Angeles Abrasion value, combined index, specific gravity, water absorption and crushing value. To prepare the SDBC specimen with and without filler such as cement and hydrated lime each 2% and different percentage of bitumen emulsion at different curing stage of the mix different emulsion contents by conducting dry Marshall Stability, soaked stability and Indirect Tensile strength test.

Mix Design of Semi Dense Cold Mix with Bituminous Emulsion The cold mix design methods have addressed the following issues:

a) Selection of correct emulsion grade and pre-wet water content for good coating.
b) Determination of total fluids/water content for optimal compaction.

c) Determination of optimum bitumen content for the desired structural properties and Resistance to moisture damage. This cold mix design involves optimization of water and bitumen emulsion for aggregates in the mix. The optimum premix water content depends on gradation and physical properties of aggregates. The aggregates are first moistened with water to wet the aggregate surface and then coated with bitumen emulsion. The different sizes of aggregates are blended in different proportions to achieve the gradation of SDBC specification.

IV. Aggregate Testing

The aggregates are tested as per IS 2386 for following properties.

A) Sieve analysis for coarse and fine aggregates.
b) Specific gravity and water absorption of coarse aggregate.
c) Specfic gravity of fine aggregates.
d)Aggregate impact value
e) Crushing Value
f) Specific gravity of cement
g) Specific gravity of hydrated lime

Table 1 Test Results of cationic Bitumen Emulsion

Bitumen emulsion of (SS-2) is used for this study and the physical properties of the bitumen emulsion were tested and the results are given in the table as per (IS 8887:2004)

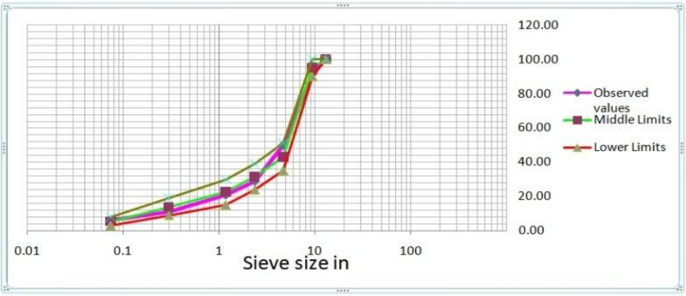
Characteristics of Bitumen emulsion	***Specifications per IS 8887:2004***	**Results obtained**
Residue on 600 micron IS Sieve	**Max .05**	0.028
Viscosity by say bolt furl viscometer, seconds:		
At 25 Deg.	30-100	35
Coagulation of emulsion at low temperature c	Nil	Nil
Residue by evaporation	Min.60%	62.84
Penetration	60-120	85
Ductility	Min.50 cm	88
. Solubility : In trichloro-ethylene, Percent by mass, Min.	Min.98%	98.97

Table 2 Aggregate Gradation for Marshall Specimens as per MORTH Specifications

Showing the Individual gradation of aggregate for SDBC(grade2) mix and its percentages

Sieve size							Total	Middle Limits	Lower Limits	Upper Limits
	12	6	Dust	12 25%	6 43%	Dust 32%				
13.2	100.00	100.00	100.00	25.00	43.00	32.00	100.00	100	100	100
9.5	65.50	100.00	100.00	16.38	43.00	32.00	91.38	95	90	100
4.75	3.00	39.40	100.00	0.75	16.94	32.00	49.69	43	35	51
2.36	0.620	4.40	84.00	0.16	1.89	26.88	28.93	31.5	24	39
1.18	0.374	0.470	65.00	0.09	0.20	20.80	21.10	22.5	15	30
0.30	0.281	0.331	33.65	0.07	0.14	10.77	10.98	14	9	19
0.08	0.079	0.099	16.19	0.02	0.03	5.99	6.04	5.5	3	8

SDBC Gradation after Blending



4.1 Marshall Specimen preparation

1 Mix the dry aggregate of batches and additive such as cement and hydrated lime different percentage of water of total weight of the mix.
2. For Present study the percentage of water is varied from 4 to 7 with an increment of .5% and obtained coating in 5.5% by visual observation.
3. After adding additive such as cement and hydrated lime varying the percent of water and got 6.04% is giving better coating by visual inspection.
4. Optimum moisture content obtained 5.5% of water for bitumen emulsion (SS2) and OMC for SS2 with additive i.e. cement and hydrated lime 6.04%

Procedure for cold mix design

1. The dry aggregate was blended into 1200g batches by combining the different aggregate sizes to the desired gradation.
2. The aggregate was used cold (at room temperature)
3. The moisture content was added to the aggregate and mixed thoroughly. The mix was left for 10-15 minutes at room temperature before adding bitumen emulsion.
4. The emulsion was added cold to the wet aggregate and mixed thoroughly for about 2 minutes. The suitability of the mix and degree of coating was then evaluated.
5. After mixing the mixture was kept in oven at 40 degree c for 72 hours. At the end of 72 hours the specimen were taken out from the oven and poured into the cold pre oiled Marshall mould.
6. In my study done the compaction of the mixture by the Marshall Compaction hammer on each side of specimen 75 blows.
7. The prepared samples were extruded after 24 hours.

In my study took 7 to 9 percent of bitumen emulsion and add 2% additive i.e. cement and hydrated lime to all percentage of bitumen emulsion and found 8% emulsion is optimum for both mixes with and without filler. In this paper putting the result of optimum emulsion content.

V. Comparison of properties of mixes without and with 2% cement and hydrated lime as filler

Optimum emulsion has been found 8% without and with filler cement and hydrated lime for 6 days and 8 days curing period. Average value of the volumetric properties, Marshall Stability, soaked Marshall Stability, Marshall flow and ITS of three mixes without and with filler such as cement and hydrated lime for 6 and 8 days curing period.

Table3 comparisons of properties of mix without filler for 6 and 8 days curing periods

Curing days.	Emulsion (%)	Gb (g/cc)	Gt (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Flow (mm)	Stability (kgs)	Soaked stability (kgs)	ITS (mpa)
6.00	8.00	2.222	2.5230	9.49	11.30	20.79	54.35	7.33	1073.10	1008.39	0.2029
8.00		2.226	2.5230	9.12	11.34	20.45	55.44	7.20	1161.00	1093.70	0.2170

Table 4 comparisons of properties of mix with filler as cement for 6 and 8 days curing periods

Curing days.	Emulsion (%)	Gb (g/cc)	Gt (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Flow (mm)	Stability (kgs)	Soaked stability (kgs)	ITS (mpa)
6.00	8	2.246	2.5330	8.23	11.5	19.71	58.2	6.70	1632.50	1551.00	0.2405
8.00		2.247	2.5330	7.84	11.5	19.36	59.5	6.50	1698.70	1612.00	0.2690

Table 5 comparisons of properties of mix with filler as hydrated lime for 6 and 8 days curing periods

Curing days.	Emulsion (%)	Gb (g/cc)	Gt (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Flow (mm)	Stability (kgs)	Soaked stability (kgs)	ITS (mpa)
6.00	8.00	2.237	2.5260	8.56	11.41	19.97	57.14	7.67	1499.60	1423.00	0.2170
8.00		2.237	2.5260	8.26	11.44	19.70	58.07	7.40	1557.30	1479.30	0.2322

Table 6 Comparisons of properties of mix without and with filler as cement and hydrated lime of 6 days curing period.

Curing days.	Emulsion	Gb (g/cc)	Gt (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Flow (mm)	Stability (kgs)	Soaked stability (kgs)	ITS (mpa)
6	8% without filler	2.222	2.523	9.49	11.30	20.79	54.35	7.33	1073.10	1008.39	0.2029
	8% cement as filler	2.246	2.533	8.23	11.50	19.71	58.20	6.70	1632.50	1551.00	0.2405
	8% hydrated lime as filler	2.237	2.526	8.56	11.41	19.97	57.14	7.67	1499.60	1423.00	0.2170

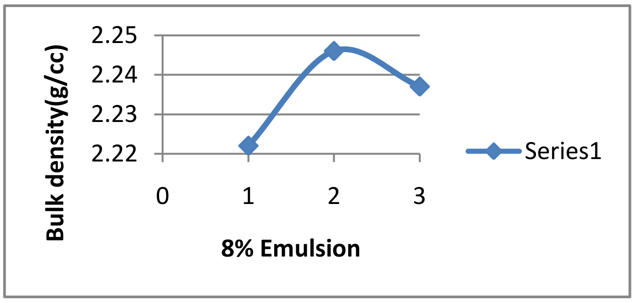


Fig. 1 Bulk density vs. Emulsion without and with filler

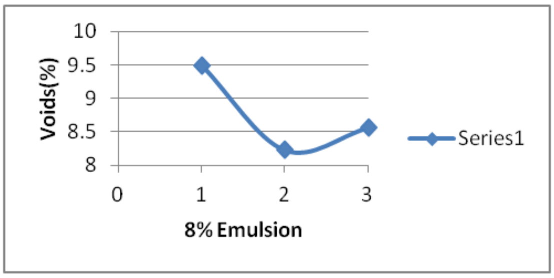


Fig. 2 Voids vs. Emulsion without and with filler

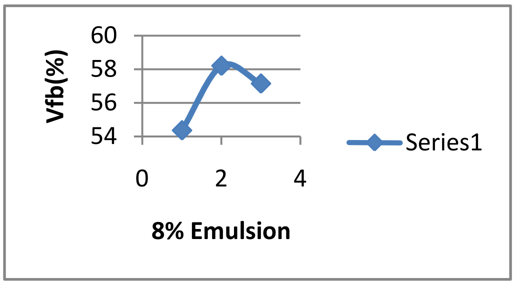


Fig. 3 Vfb vs. Emulsion without and with filler

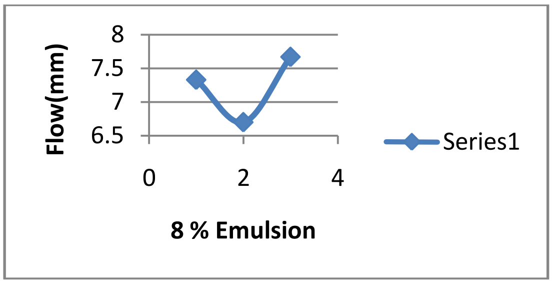
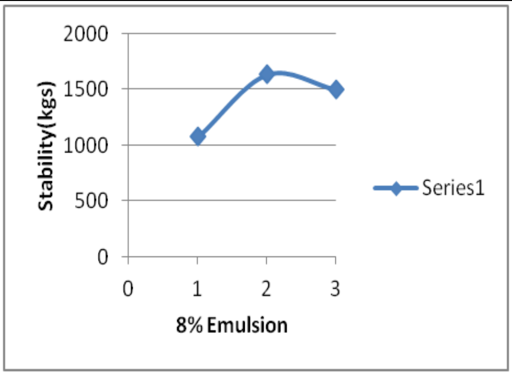


Fig. 4 Flow vs. Emulsion without and with filler



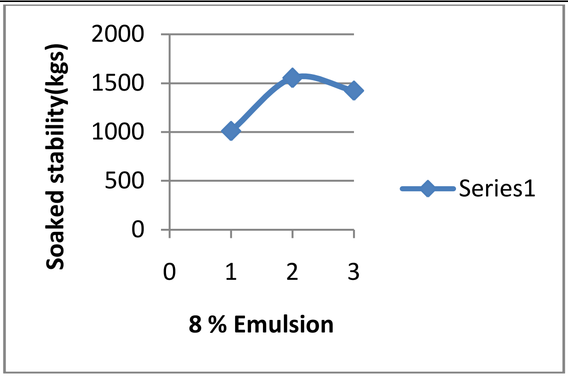


Fig. 5 Stability vs. Emulsion without and with filler Fig. 5 Soaked stability vs. Emulsion without and with filler

Note: 8% Emulsion is the mixes of without and with cement and hydrated lime as filler 2% each.

Table 7 Comparisons of properties of mix without and with filler as cement and hydrated lime of 6 days curing period .

Curings days	Emulsion	Gb	Gt	Vv	Vb	VMA	VFB	Flow	Stability	Soaked stability	ITS
		(g/cc)	(g/cc)	(%)	(%)	(%)	(%)	(mm)	(kgs)	(kgs)	(mpa)
6	8% without filler	2.222	2.523	9.49	11.3	20.8	54.35	7.33	1073.1	1008.39	0.203
	8% cement as fille	2.246	2.533	8.23	11.5	19.7	58.2	6.70	1632.5	1551	0.241
	hydrated lime as fi	2.237	2.526	8.56	11.41	20	57.14	7.67	1499.6	1423	0.217

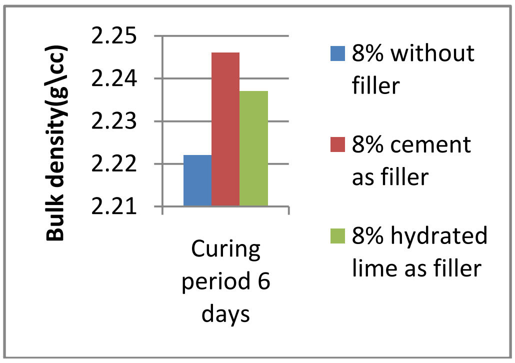


Fig. 6 curing period vs. Bulk density

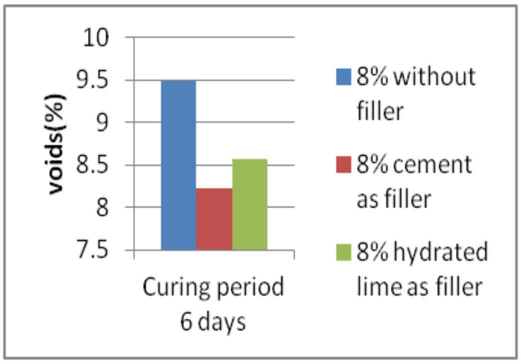


Fig. 7 Curing period vs. voids in total mix

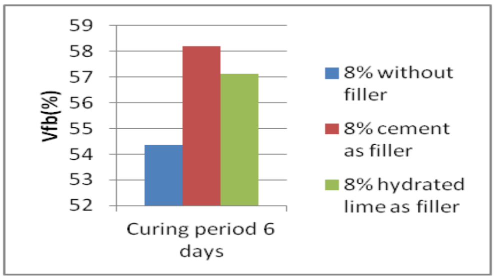


Fig. 8 Curing period vs. voids filled with bitumen

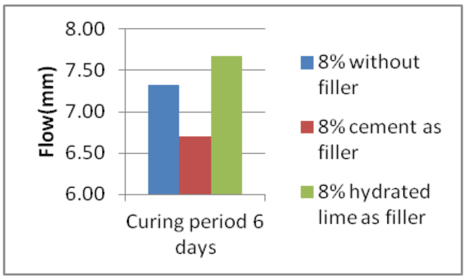


Fig.9 curing period vs. flow

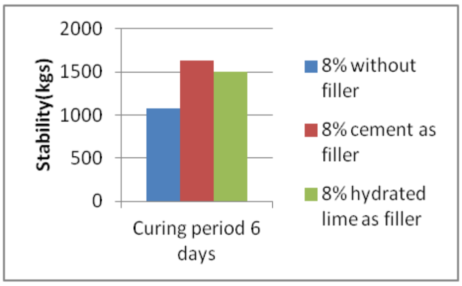


Fig.10 curing period vs. Stability

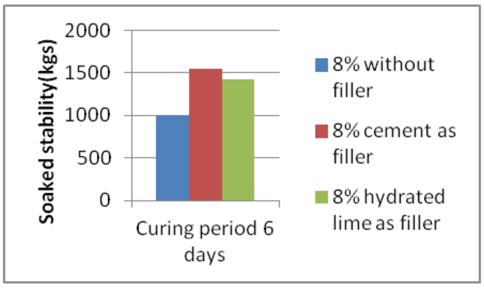


Fig.11 Curing period vs. soaked stability

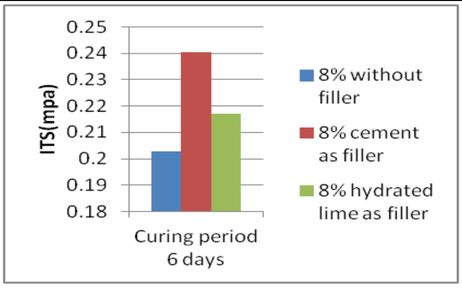


Fig..12 curing period vs. ITS

Table 8 Comparisons of properties of mix without and with filler as cement and hydrated lime of 8 days curing period

Curing days	Emulsion	Gb	Gt	Vv	Vb	VMA	VFB	Flow	Stability	Soaked stability	ITS
		(g/cc)	(g/cc)	(%)	(%)	(%)	(%)	(mm)	(kgs)	(kgs)	(MPa)
8	8% without filler	2.226	2.5	9.12	11.34	20.45	55.44	7.20	1161.00	1093.70	0.2170
	8% cement as filler	2.247	2.5	7.84	11.50	19.36	59.50	6.50	1698.70	1612.00	0.2690
	8% hydrated lime as filler	2.237	2.5	8.26	11.44	19.70	58.07	7.40	1557.30	1479.30	0.2322

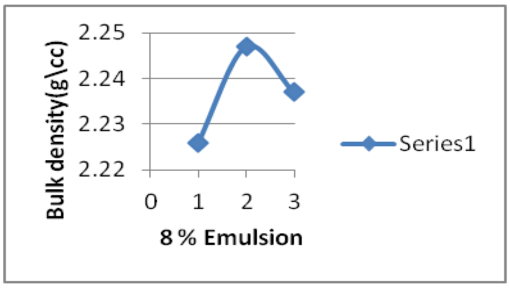


Fig. 13 Bulk density vs. Emulsion without and with filler

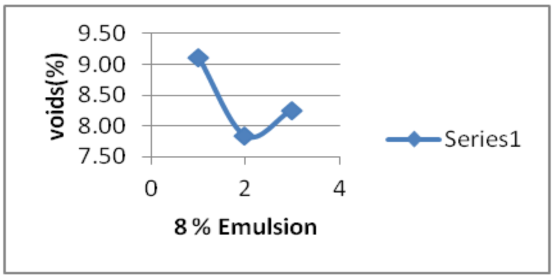


Fig. 14 Voids vs. Emulsion without and with filler

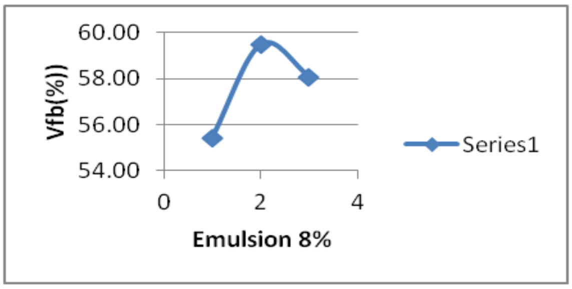


Fig. 15 Vfb vs. Emulsion without and with filler

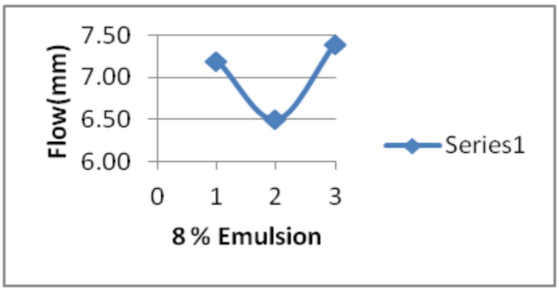


Fig. 16 Flow vs. Emulsion without and with filler

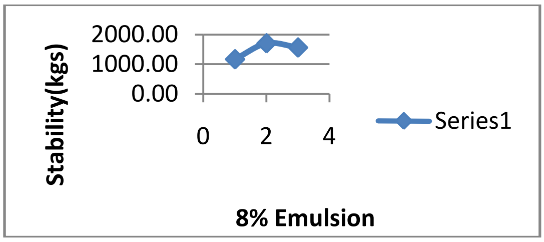


Fig. 17 Stability vs. Emulsion without and with filler

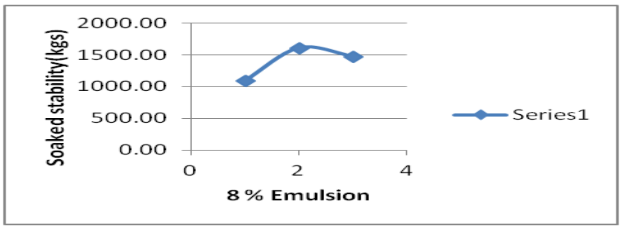


Fig. 18 Soaked Stability vs. Emulsion without and with filler

Note: 8% Emulsion is the mixes of without and with cement and hydrated lime as filler 2% each.

Table 9 Comparisons of properties of mix without and with filler as cement and hydrated lime of 6 days curing period.

Curing days	Emulsion	Gb	Gt	Vv	Vb	VMA	VFB	Flow	Stability	Soaked stability	ITS
		(g/cc)	(g/cc)	(%)	(%)	(%)	(%)	(mm)	(kgs)	(kgs)	(MPa)
8	8% without filler	2.226	2.5	9.12	11.34	20.45	55.44	7.20	1161.00	1093.70	0.2170
	8% cement as filler	2.247	2.5	7.84	11.50	19.36	59.50	6.50	1698.70	1612.00	0.2690
	8% hydrated lime as filler	2.237	2.5	8.26	11.44	19.70	58.07	7.40	1557.30	1479.30	0.2322

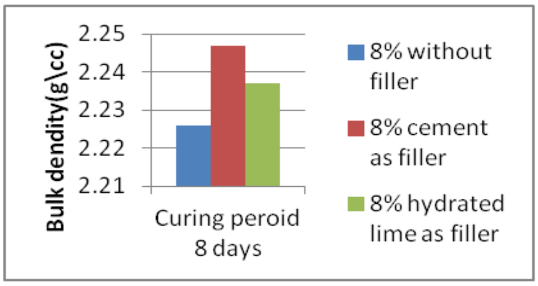


Fig.19 Curing period vs. Bulk density

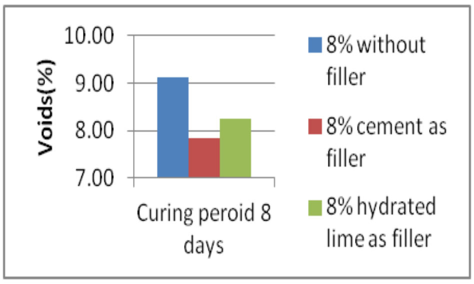


Fig.20 Curing period vs. Voids

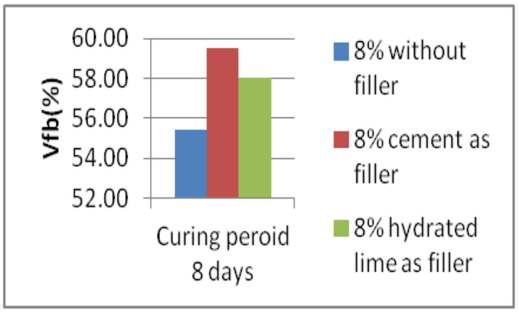


Fig.21Curing period vs. Vfb

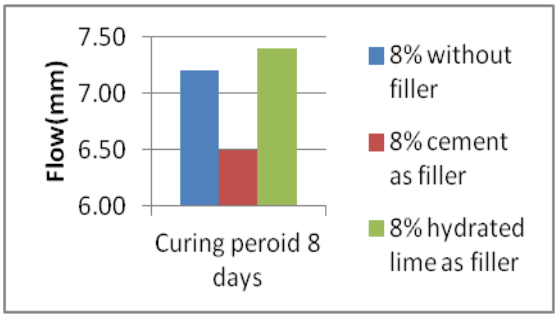


Fig.22 Curing period vs. flow

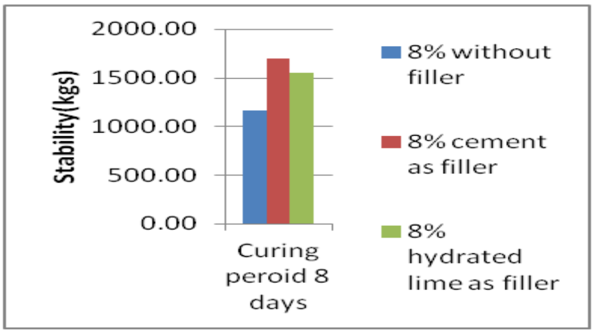


Fig.23. Curing period vs. stability

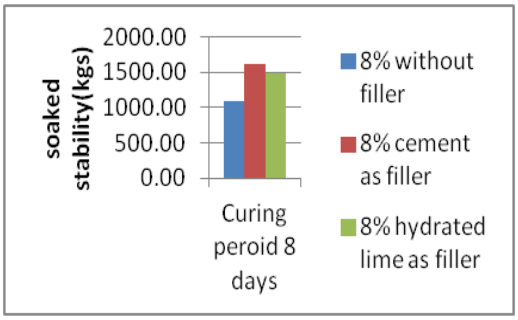


Fig.24 Curing period vs. soaked stability

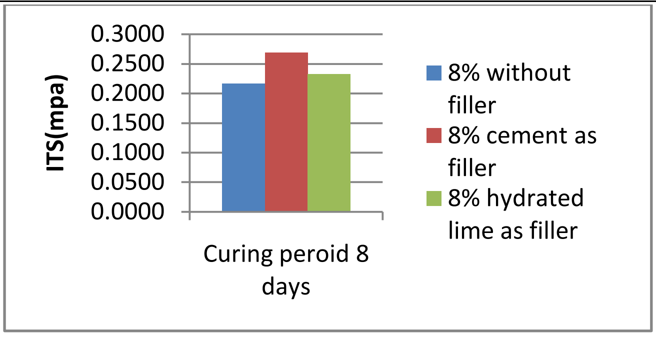


Fig.25 Curing period vs. ITS (mpa)

VI. Conclusions

- The optimum Emulsion content (OEC) is same for three mixes with and without filler such as cement and hydrated lime.
- The bulk density, dry and soaked Marshall Stability, Indirect tensile strength increased with the increase the curing period without and with the addition of 2% cement and hydrated lime as filler.
- Cement as filler provides better results as compared to as filler hydrated lime and without filler.
- Voids in total mix, flow and voids in Mineral aggregates reduced with increase in curing period and with the addition of cement and hydrated lime as filler.
- Six days curing period can be considered as optimum to achieve better properties and results.

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